ENERGY FLOWS IN THE INDIAN ECONOMY 1981-82

An Overview

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This short note, intended as an introduction to colleagues new to the energy field, presents the main features of the energy scenario in India in 1981-82. Wherever possible, energy units based on the First Law of Thermodynamics, as well as those based on the Second Law, have been used. Accounting of energy using the First Law allows one to translate energy from various sources into coal equivalent as MTCE (million tonne coal equivalent). Measurements in MTCE equate the number of Joules obtained from a particular quantity of energy source to the Joules obtainable from so many million tonnes of coal (e.g. 1 million tonnes of firewood = 0.98 MTCE). Energy is counted using units based on the Second Law of Thermodynamics in terms of MTCR (million tonne coal replacement). This yardstick measures how many million tonnes of coal burnt in standard industrial-type furnaces will produce an equivalent quality and amount of energy delivered by the given quantity of a particular energy source. This unit of measurement (unlike MTCE) takes into account thermodynamic efficiencies of conversion, as well as differing efficiencies of combustion.

Figure 1: One can conveniently divide all the major energy sources between "traditional" and "non-traditional", defining any energy source that has been exploited for more than 10 generations (300 years) in our past as "traditional". In this context, the

traditional[A]* energy sources are: animal power, firewood, animal dung, and agriculture waste. The non-traditional energy sources are: coal[B], hydro-electricity, nuclear fuels, oil and oil products. The contribution from the new & renewable energy technologies is still too small to show up on this figure.

Inclusive of the fossil fuel products used for non-energy purposes (coal tar for surfacing roads, non-energy petroleum products etc.), India's annual energy production is about 8×10^{18} Joules (= 7.6 Quads) [C]. The per capita daily energy consumption is only about 27.34 million Joules, (26 K BTUs)[D]. The contributions of specific traditional and non-traditional sources to the total energy produced are shown in Figure 1.

In MTCE units, Indian energy production is almost evenly divided into traditional and non-traditional sources (45.56% and 54.41% respectively). On the other hand, using units based on the Second Law (i.e. MTCR units), the proportion of energy produced from traditional and non-traditional sources is quite different: 30.4% traditional and 69.6% non-traditional. This reflects the higher quality of energy available from the non-traditional sources, as well as the lower combustion efficiencies associated with equipment using traditional fuels.

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* Alphabets in square brackets refer to notes at the end of the text.

The total annual energy production here includes only those sources of energy which are a direct input into the economic process. Thus solar energy captured in foodgrain and consumed by human beings is not accounted for, but solar energy captured in fire-wood will be indirectly accounted for in the form of the useful heat content of firewood.

As a result of extreme poverty human beings are commonly employed in place of animals or machines as sources of mechanical power. Common examples are cycle-rickshaw peddlers, labour for pushing loaded carts and wagons, rickshaw pullers, poor peasants pulling ploughs, agricultural irrigation using human power etc. Energy contribution from human muscular power has been excluded here primarily because its inclusion in energy accounting is contested by some experts concerned about the difficulty in defining which human activities can be legitimately considered as contributing energy to the economy. The present authors would propose inclusion of only those human activities where labour provides mechanical power that could otherwise be provided by animal or machine. On a per capita basis, contribution from human muscular energy to economic activity in India would then amount to about 250 BTU/day or about 1% of the total.

Figure 2: The break-up of traditional and non-traditional energy consumption[E] by the urban and rural sectors of the economy is shown in this figure. Total urban and rural energy consumption figures are given in both First Law units (10^{15} Joules) and Second Law units (MTCR). It is interesting to note that in MTCR units, the break-up of energy use into traditional and non-traditional sources shows that the urban and rural users are roughly mirror images of each other; the break-up is about 80:20 for rural population and 20:80 for urban population. Also note that while rural population is about 74% of the total, it accounts for less than 5% of total non-traditional energy consumption.

In arriving at this figure, we put the energy consumption of all non agro-industries with the urban sector. Since the methodology for breakup of energy consumption in the transportation sector between urban and rural uses is not uniquely defined, we have included all mechanized transportation with urban uses. Domestic use was apportioned by population. Agricultural and agro-industrial energy use is taken as rural.

Figure 3: Coal is the single largest source of non-traditional energy for India. Coal production, nearly 125 MT for 1981-82 in First Law terms accounts for over 61% of total non-traditional energy produced and over 33% of total energy produced in India. The average

annual growth rate of coal production, which was 2.7% for the decade 1961-1971, more than doubled in the next decade to 5.6%, mainly due to the two large increases in coal production which took place in the years immediately following the two oil price shocks of 1973-74 and 1979-80. In these two years coal production increased at annual rates of 13% and 10% respectively.

Of the total production of 125 MT, nearly 79% (by weight) is non-coking coal (the remaining 21% is almost exclusively consumed by the steel industry as coke. The percentages shown in Fig.3 regarding this break up refer to the energy content, not weight). The five industrial enterprises shown in the figure consume about 70% of the coal production. Other consumers, all with shares of less than 3% individually, have been put together in the category "Others". One should also mention here that the crucial role played by coal in the Indian economy is reflected in its being the single largest commodity transported by the Indian Railways [F].

India's estimated coal reserves [G] are shown in Table I.

Table 1

INDIA'S COAL RESERVES (1983 ESTIMATES)
MILLIONS OF TONNES

Type of Coal	Depth below Ground		Total
	0m - 600m	600m - 1200m	
Coking	16,568	4,707	21,275
Non-coking	90,289	15,684	105,973
		GRAND TOTAL	127,248

Most of the coal is close to the surface; mining deeper will not tap proportionately larger coal reserves. At the present rate of growth of coal consumption these reserves will last us for another 72 years.

Figure 4: Energy supply and demand patterns of oil are shown in this figure. Demand for oil and oil products is met through both domestic production as well as imports. Of the total crude oil available, 52.7% is domestically produced with imports accounting for the balance (47.3%) (1983-84 share of imports was down to 38%). Refinery products contain 98% of the energy present in the crude oil before processing. Industrial and transport sectors account for approximately 80% of petroleum energy consumed.

Indian crude oil is "heavy" (i.e. it has a high proportion of heavy distillates such as fuel oil, lubes

and bitumen), and our oil imports consist almost exclusively (94%) of middle distillates (Jet fuels, kerosene, high and low speed diesels) of which we are short. Since 1981-82 India has started exporting its heavy crude (exports were 4.4 million tonnes in 1982-83). The oil production also has been increasing rapidly from 16.2 million tonnes in 1981-82 to about 21 million tonnes in 1982-83, and to 26 million tonnes in 1983-84. Most of the increase in production is exported and light crude imported in exchange. India's oil reserves were estimated (in January 1983) at 526 million tonnes. At the current rate of growth of extraction these will be exhausted in another 9 years. If the rate of growth of extraction is slowed down to only 10% annually, the reserves will be exhausted 11 years from now. This is much shorter than the estimated time remaining till recoverable world oil reserves get exhausted at the present rate of growth of world oil production, which will happen between 30 to 40 years from now.

India's resources of natural gas have been estimated in January 1983 at 475 billion cubic meters. Since most of the gas extraction is in the form of associated gas (i.e. gas dissolved in extracted oil), the natural gas production is much larger than India's present gas-handling capacity and a large quantity of gas (45% in 1982-83) is being flared daily. The annual gas production in 1981-82 was 3.85 Billion Cubic Meters

(BCM) which increased to 4.94 BCM in 1982-83, and to more than 5.70 BCM in 1983-84.

Figure 5: Source-wise production and sector-wise consumption of electricity is shown in this figure.

Total installed capacity in the year 1981-82 stood at 35611 MW. Hydro and Thermal power plants together account for 97% of this, the balance being Nuclear.

The industrial sector is the largest consumer of electricity (share in total consumption: 62%). The percentage share of this sector in the total electricity consumption has however declined from 74.5% in 1960-61 to 70.6% in 1970-71 and further to the present level. This decline has been offset by the increasing demand from the agricultural sector whose share has risen from 5% in 1960-61 to 9% in 1970-71 to more than 15% in 1981-82. The shares of the other sectors have been more or less constant over the last two decades.

Figure 6: Various components of production of traditional energy sources are shown in this figure.

Firewood is the single largest energy source for India. Though 33% of our land is under the Forestry Departments, actually only about 11% of the land area

(36 million hectares) is under tree cover and this is being depleted due to deforestation at the rate of about 1 million hectares per year.

Timber and pulp and paper industries account for a considerable extent of tree-felling (experts differ as to quantitative estimates of this extent). Also, more than 55% of the energy-content of wood-fuel consumed in the country comes from branches, twigs, sawdust and wood shavings. Thus not all of the rapid deforestation of India can be blamed on use of wood-fuel as an energy source. Furthermore, the productivity of Indian forests is estimated to be about 0.4 dry tonnes/hectare/year (compare this with productivity of more than 20 dry tonnes/hectare/year for commercially managed forests in the USA).

India has about 250 million heads of cattle which produce energy in the form of dung and draft animal power. The total dung production in the year 1981-82 has been estimated to be around 118 million dry tonnes and the animal motive power available from the 80 million draft animals is about 30,000 MW (compare this with the total electric generation capacity of 35,000 MW). It is estimated that about 40% of the dung is collected and burned in chullahs which have an average combustion efficiency of 7% . An insignificant fraction of the dung is used in biogas plants. If 70% of the dung

produced is used in biogas plants one would get energy worth 40 million tonnes of coal on a replacement basis in addition to fertilizer slurry. The draft animals are used (also very inefficiently) for about 800 hours each year to produce an equivalent of 30 x 10^9 KWH of motive energy (this is more than 10 times the amount of energy used in electrified transport - mostly by electrified railways).

Out of 203 million tonnes of agricultural waste produced annually, 40 million tonnes is burned, mostly extremely inefficiently for domestic uses (thermal efficiencies are typically in the range of 5% - 8%). The rest of the agwaste is used for animal fodder, thatching, composting, etc.

CONCLUDING REMARKS

Traditional sources of energy make a major contribution (close to 50%) to the total energy consumption in India but are often not given the recognition they deserve. While the impact of the energy sector on the rest of the economy has been strongly felt since the early seventies, not much effort has been made towards improving the efficiency of utilization of these sources of energy. Firewood, dung and cropwaste are still being used almost entirely for burning in chulhas of abysmally low efficiencies, with only a very small percentage

being consumed for biogas production or in wood gasifiers. The use of new renewable energy sources (i.e. solar, wind or tidal energy) is negligible. The poor quality of data regarding the traditional and renewable energy sources is a further indication of the long standing neglect of this sector.

The average per capita daily energy consumption in India is poor (27.34 M Joules). Furthermore there is an enormous difference between the daily per capita energy consumption for rural and urban populations (15.2 MJ and 61.0 MJ per day respectively). Rapid urbanization of India's population will probably lead to a rapid increase in the energy demand. Raising the living standard of the bulk of India's population will also need a several-fold increase in per capita energy consumption. This additional energy will have to be obtained by tapping renewable sources of energy, and by improving the current low efficiency of energy use. Per capita income and per capita energy consumption are plotted [H] for several countries in Fig.7. Apart from the obviously low position occupied by India in terms of per capita income or energy use, what is more alarming is that India has (together with UK, Canada and USA), one of the most energy-inefficient economies in the world. The response of the economies of several countries to the energy crisis is shown in Fig. 8A. India's response, shown in Fig. 8B, gives no indication

of any consistent trend in improving its energy efficiency; it appears essentially random. Significant and coordinated effort is necessary to avoid leading the Indian economy into deep trouble as the world fossil fuels get exhausted over the next 50 years.

The authors very much welcome comments on and corrections to the overall energy picture presented in the preceding pages.

[A] See also: "A Classification of Energy Sources", Ashok Gadgil and Dilip Ahuja, TERI discussion paper TERI-D4, (1983)

[B] Though there is archeological and historical evidence for use of coal dating back to more than 1500 years, coal is denoted as "non-traditional" since its use has become significant only relatively recently.

[C] See Appendix I for definitions and conversion units.

[D] Note for comparison that in the United States the per capita energy consumption is 950 K BTU's which is about 36 times this amount.

[E] After taking into account the transmission and distribution losses.

[F] Proceedings, "Workshop on Environmental Guidelines for Coal Transportation", November 14-17, 1983, Tata Energy Research Institute, New Delhi.

[G] Estimates published by Bureau of Industrial Costs and Prices, Government of India (1983). The Geological Sruvey of India had estimated in September 1978 the total coal reserves to be 111,878 MT.

[H] The following procedure has been followed for converting currencies into a common unit (US Dollars) for Figures 7, 8A and 8B. The currencies are converted at the exchange rates corresponding to the last year shown on the figure. The previous years' data are then adjusted using official figures for the inflation rates for each currency for the corresponding years.

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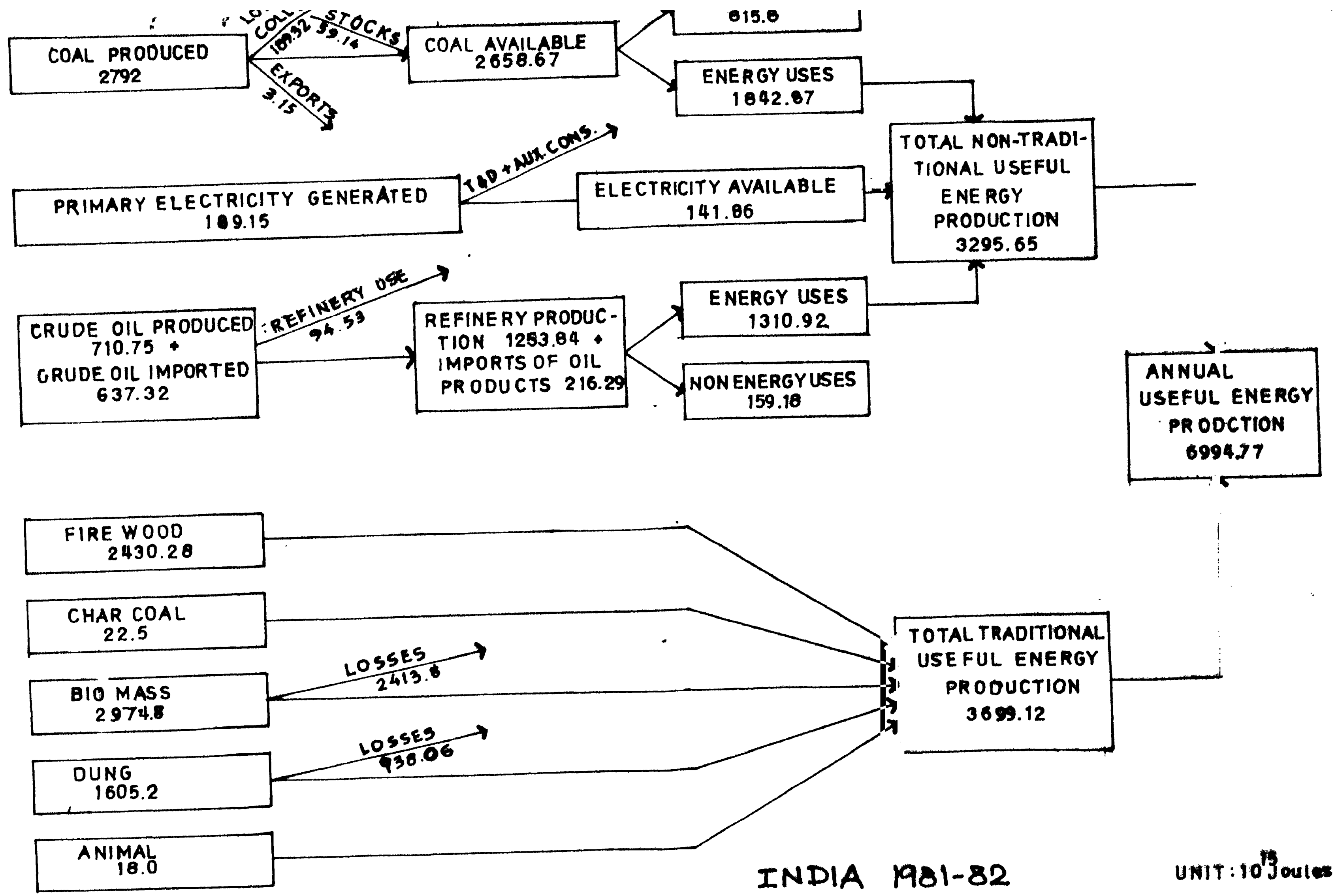

COAL PRODUCED
2792
STOCKS
39.14
EXPORTS
3.15
COAL AVAILABLE
2658.67
615.6
ENERGY USES
1842.87
PRIMARY ELECTRICITY GENERATED
189.15
T&D + AUX. CONS.
ELECTRICITY AVAILABLE
141.86
TOTAL NON-TRADITIONAL USEFUL ENERGY PRODUCTION
3295.65
CRUDE OIL PRODUCED
710.75 +
CRUDE OIL IMPORTED
637.32
REFINERY USE
94.53
REFINERY PRODUCTION 1253.84 + IMPORTS OF OIL PRODUCTS 216.29
ENERGY USES
1310.92
NON ENERGY USES
159.18
ANNUAL USEFUL ENERGY PRODCTION
6994.77
FIRE WOOD
2430.28
CHAR COAL
22.5
BIO MASS
2974.8
LOSSES
2413.8
DUNG
1605.2
LOSSES
936.06
ANIMAL
18.0
TOTAL TRADITIONAL USEFUL ENERGY PRODUCTION
3699.12
INDIA 1981-82
UNIT: 10^{15} Joules

FIG. 1

INDIA 1981-82

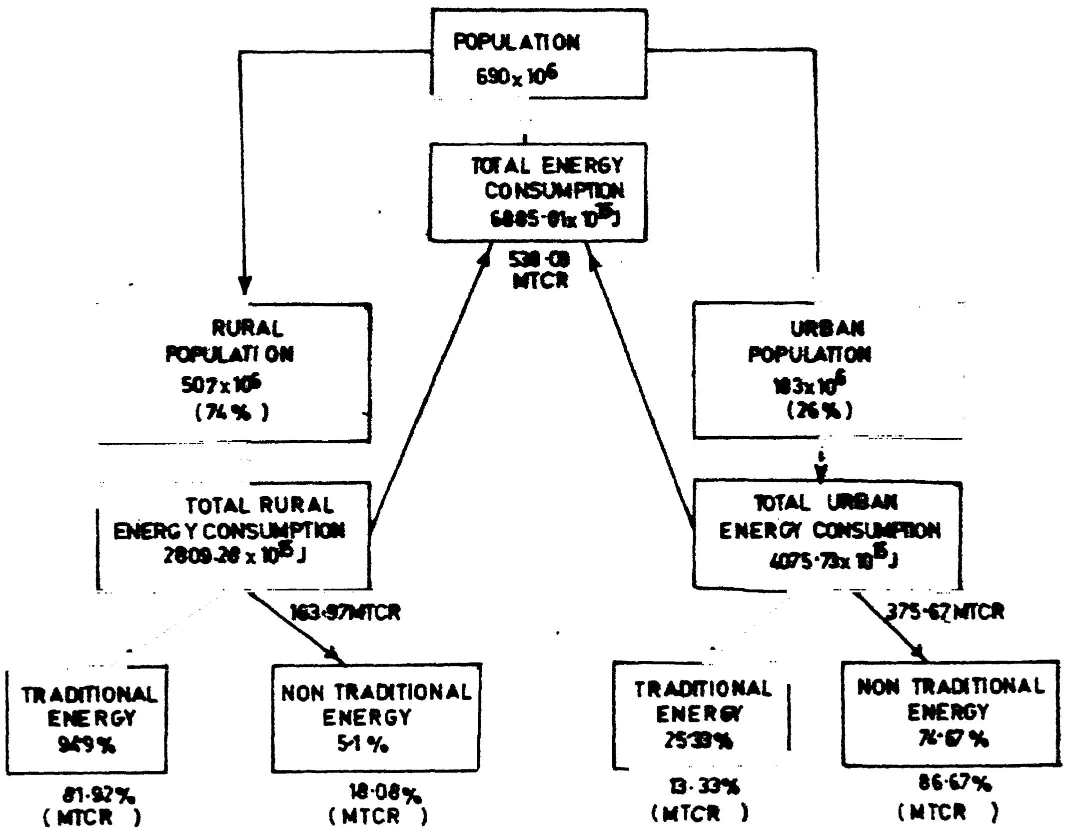
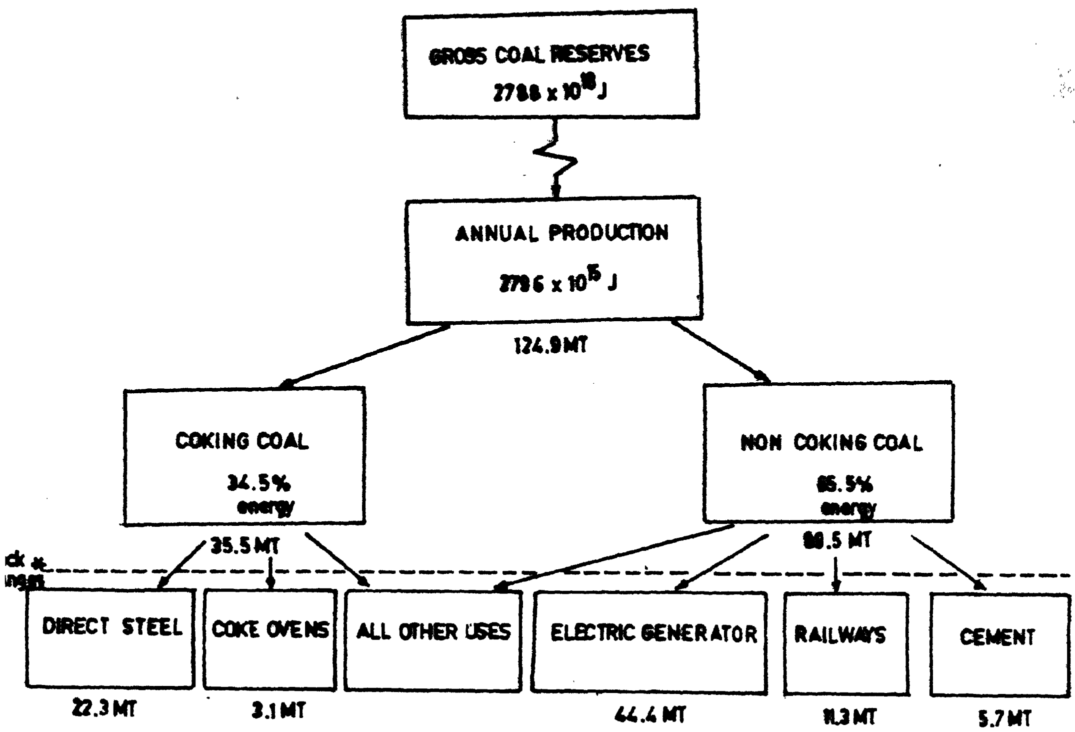


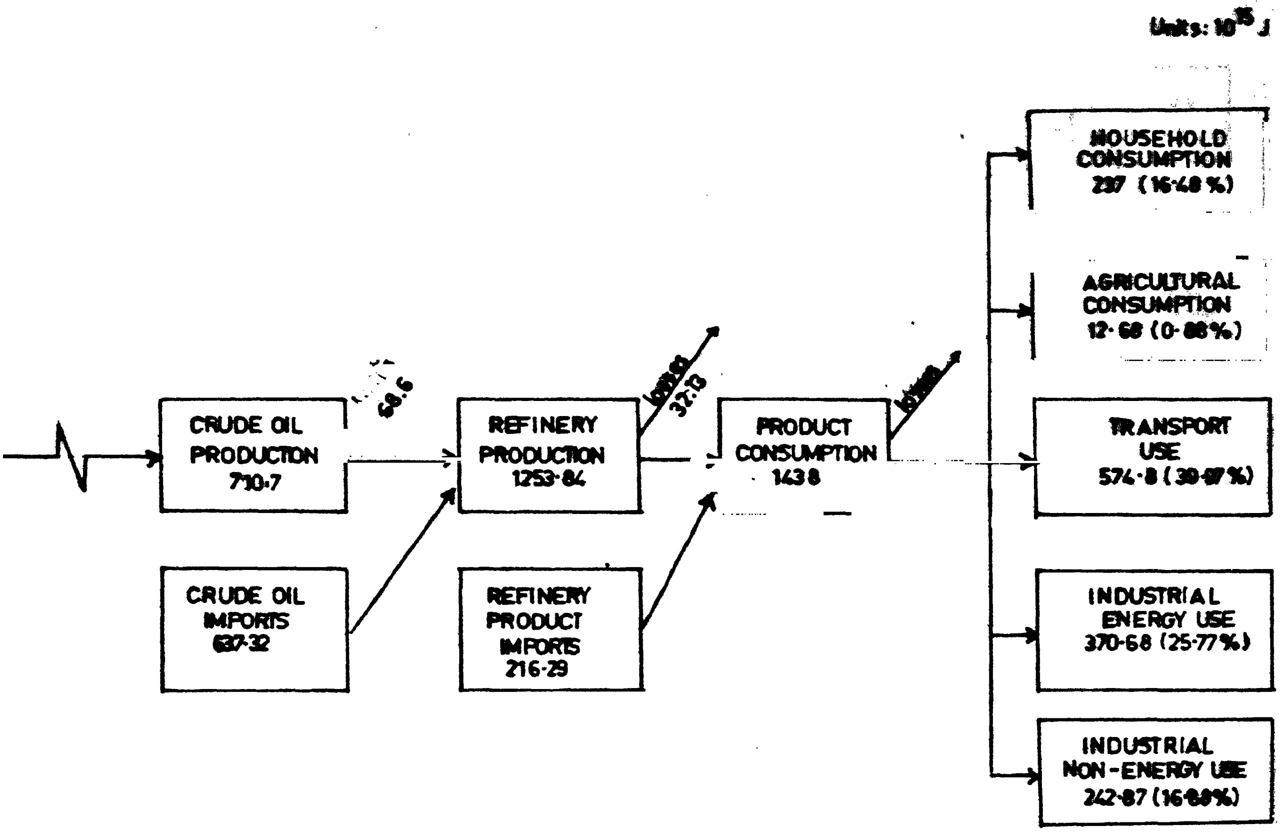
FIG. 2

COAL INDIA 1981-82



These include 0.5 MT of net imports, and changes in pithead and industrial stocks.

FIG. 3



Units: 10^{15} J
CRUDE OIL PRODUCTION 710.7
CRUDE OIL IMPORTS 637.32
58.6
REFINERY PRODUCTION 1253.84
32.13
REFINERY PRODUCT IMPORTS 216.29
PRODUCT CONSUMPTION 1438
HOUSEHOLD CONSUMPTION 237 (16.48 %)
AGRICULTURAL CONSUMPTION 12.68 (0.88%)
TRANSPORT USE 574.8 (39.97%)
INDUSTRIAL ENERGY USE 370.68 (25.77%)
INDUSTRIAL NON-ENERGY USE 242.87 (16.88%)

FIG. 4

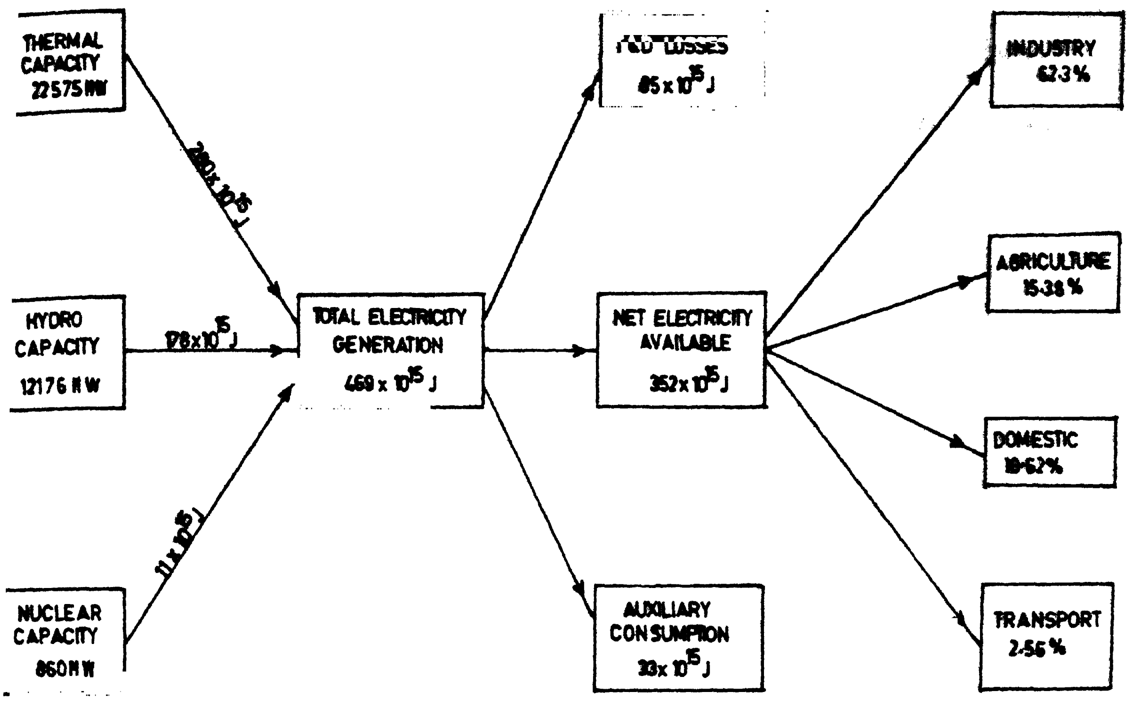
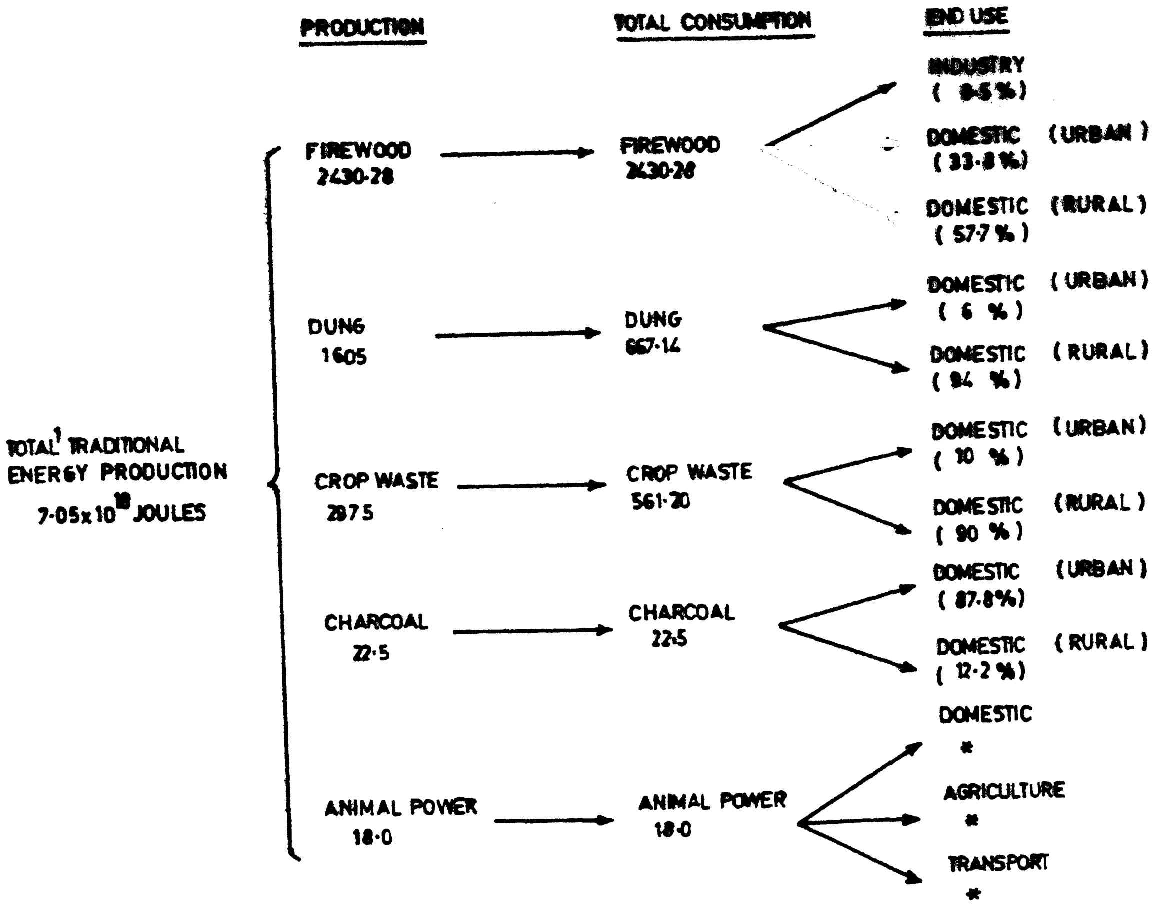

THERMAL CAPACITY 22575 MW
HYDRO CAPACITY 12176 MW
NUCLEAR CAPACITY 860 MW
280 x 10^15 J
178 x 10^15 J
11 x 10^15 J
TOTAL ELECTRICITY GENERATION 469 x 10^15 J
T&D LOSSES 85 x 10^15 J
AUXILIARY CONSUMPTION 33 x 10^15 J
NET ELECTRICITY AVAILABLE 352 x 10^15 J
INDUSTRY 62.3 %
AGRICULTURE 15.38 %
DOMESTIC 19.62 %
TRANSPORT 2.56 %

FIG. 5



* : Break-up not known
1 : Includes that part which is not collected or lost

FIG. 6

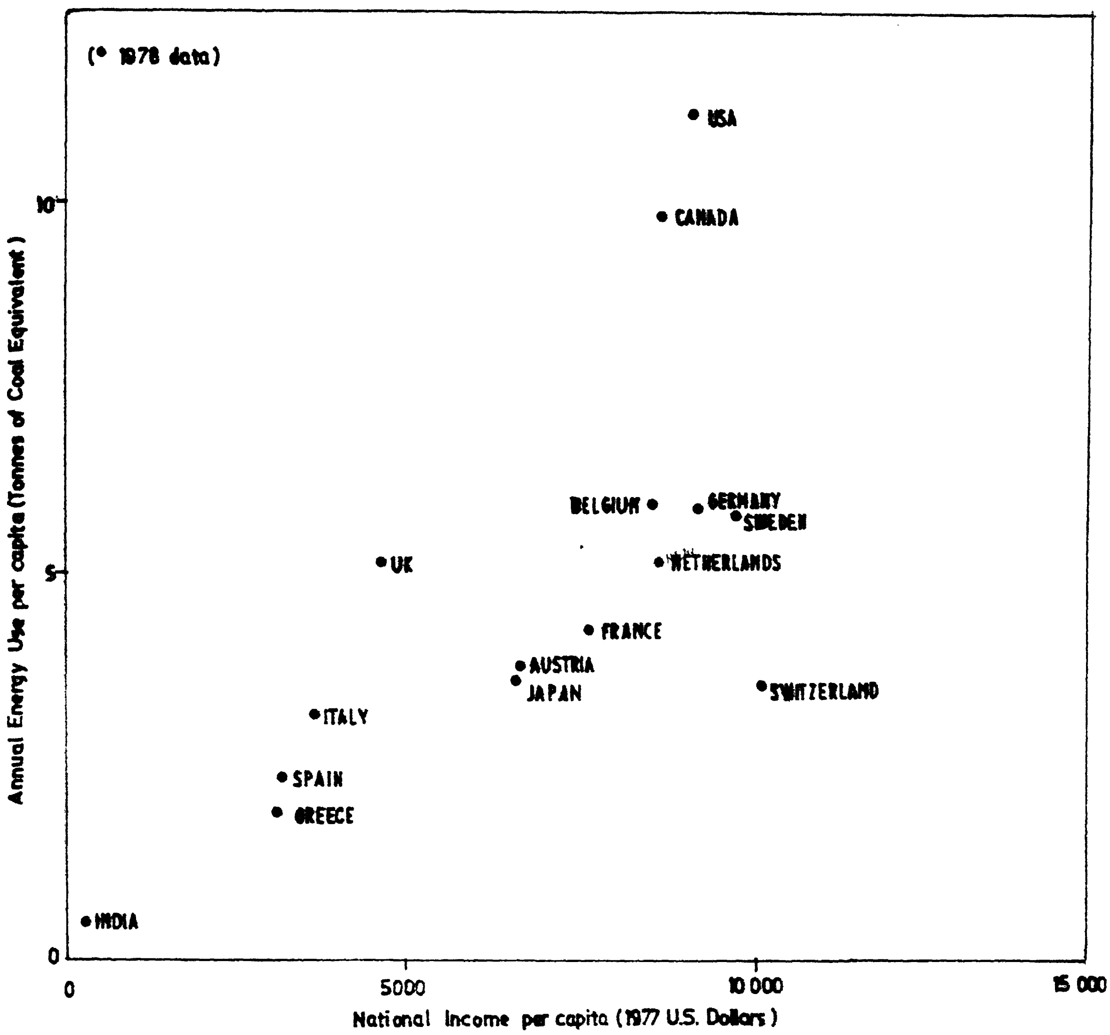
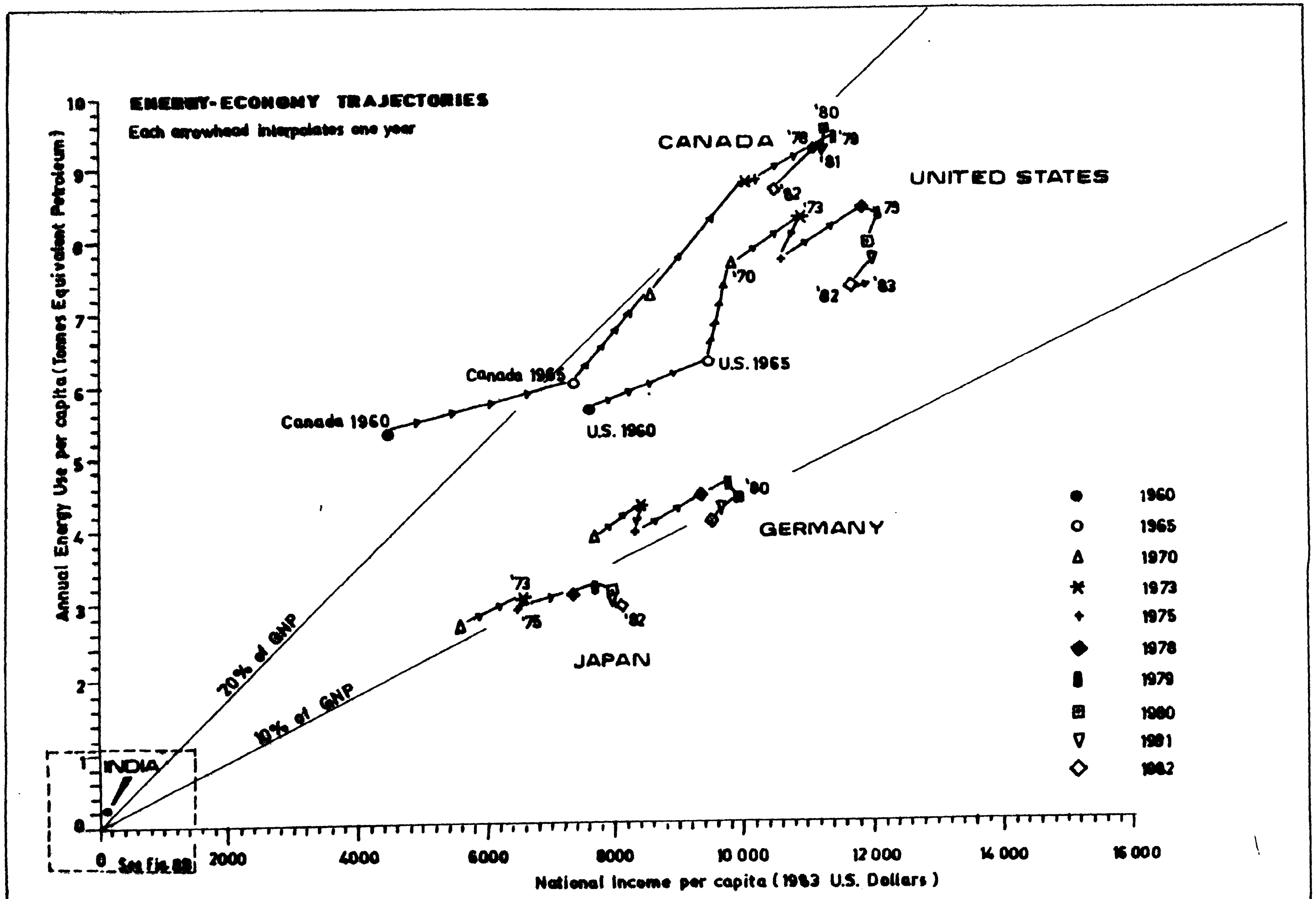

(* 1978 data)
USA
CANADA
BELGIUM
GERMANY
SWEDEN
UK
NETHERLANDS
FRANCE
AUSTRIA
JAPAN
SWITZERLAND
ITALY
SPAIN
GREECE
INDIA
10
5
0
0
5000
10 000
15 000
Annual Energy Use per capita (Tonnes of Coal Equivalent)
National Income per capita (1977 U.S. Dollars)

FIG. 7



ENERGY-ECONOMY TRAJECTORIES
Each arrowhead interpolates one year
Annual Energy Use per capita (Tonnes Equivalent Petroleum)
National Income per capita (1983 U.S. Dollars)
0
2000
4000
6000
8000
10 000
12 000
14 000
16 000
1
2
3
4
5
6
7
8
9
10
CANADA
UNITED STATES
GERMANY
JAPAN
INDIA
Canada 1960
Canada 1965
U.S. 1960
U.S. 1965
'70
'73
'75
'78
'79
'80
'81
'82
'83
20% of GNP
10% of GNP
See fig.
1960
1965
1970
1973
1975
1978
1979
1980
1981
1982

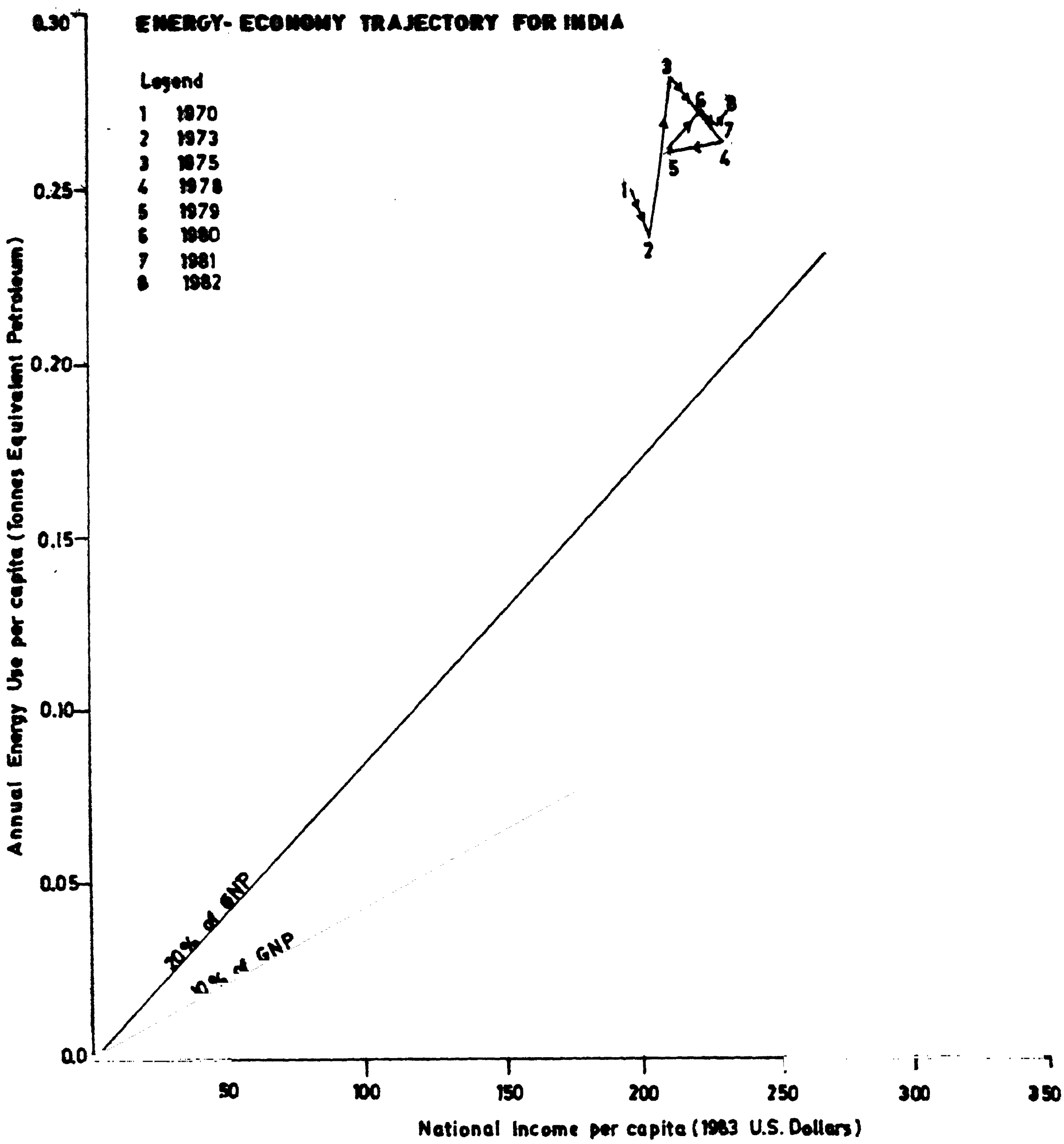

ENERGY-ECONOMY TRAJECTORY FOR INDIA
Legend
1 1970
2 1973
3 1975
4 1978
5 1979
6 1980
7 1981
8 1982
Annual Energy Use per capita (Tonnes Equivalent Petroleum)
0.30
0.25
0.20
0.15
0.10
0.05
0.0
20% of GNP
10% of GNP
50
100
150
200
250
300
350
National income per capita (1983 U.S. Dollars)

FIG. 8B

tonne of oil = 7.3 barrels of oil = 1000 Kg of oil

quad =	1.72E8 bar. oil =	9.65E8 ft³ oil =	7.24E9 gal. oil =	1E10 therms =	2.93E11 kwh =	2.52E14 kcal =	1E15 BTU =	1.05E15 kJ =	7.81E17 ft#
	1 bar. oil =	5.6 ft³ oil =	42 gal. oil =	58 therms =	1700 kwh =	1.47E6 kcal =	5.8E6 BTU =	6.1E6 kJ =	4.5E9 ft#
		1 ft³ oil =	7.48 gal. oil =	10.4 therms =	304 kwh =	2.63E5 kcal =	1.04E6 BTU =	1.09E6 kJ =	8.04E8 ft#
			1 gal. oil =	1.38 therms =	40.5 kwh =	34800 kcal =	1.38E5 BTU =	1.45E5 kJ =	1.08E8 ft#
				1 therms =	29.3 kwh =	25200 kcal =	1E5 BTU =	1.05E5 kJ =	7.81E7 ft#
					1 kwh =	861 kcal =	3410 BTU =	3580 kJ =	2.67E6 ft#
						1 kcal =	3.97 BTU =	4.18 kJ =	3.10E3 ft#
							1 BTU =	1.05 kJ =	781 ft#
								1 kJ =	741 ft#

The following conversion rates are presently used by the Govt. of India:

1Kg Coal Equivalent = 0.5Kg Crude Oil = 8.13KWH = 2.1Kg Dry Dung = 1.43Kg Ag. Waste = 1.05Kg Firewood
= 0.73Kg Charcoal
= 20900 KJ

1Kg Coal Replacement = 0.15Kg Crude Oil = 1 KWH = 2.5Kg Dry Dung = 1.73Kg Ag. Waste = 1.05Kg Firewood
= 0.73Kg Charcoal

Based on current research on combustion efficiencies of various fuels the values for Coal Replacement units may be larger in terms of various traditional fuels than shown above.